SOME SYNOPTIC ASPECTS OF A CHANGE IN WEATHER REGIME DURING FEBRUARY 1950

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INTRODUCTION

Beginning near the end of the first week and ending during the third week of February 1950, the weather regime over the United States underwent a complete change from the abnormal conditions which had persisted during January and the early part of February. The change was marked by a moderation of extreme cold in the northwestern portion of the country (and western Canada) and a return from unseasonable warmth to more normal conditions in the East. The transition period was accompanied by a series of storms moving across the United States and Canada, one of which produced the first heavy and lasting snow cover of the season in the northeastern part of the United States. The processes by which a change-over from one regime to another takes place are not fully understood, but in the present discussion some synoptic aspects of the change-over are traced, together with certain associated physical and dynamical factors, with particular emphasis on inertia effects evident in observed upper wind patterns [1,2]. An attempt is made to point out features related to short-term forecasting problems rather than to explain the causes of the change-over.

GENERAL SYNOPTIC FEATURES

The anomalous features of the circulation during the early part of February may be seen by comparing figures 1 and 2. Figure 1 (based on [3,4]) shows the normal sea-level pressure and normal 700-mb. pattern for February, and figure 2 the corresponding average conditions for the first 5 days of February 1950. Figure 2 shows that the cold air flow, which is normally southward across the Hudson Bay area into northeastern United States was displaced far to the westward, resulting in cold weather in western Canada and northwestern United States and mild conditions over the United States east of the Rockies. Other important anomalies in figure 2 include a cold surface High over the Great Basin region, and a large surface High over the Aleutian Islands, the latter being of

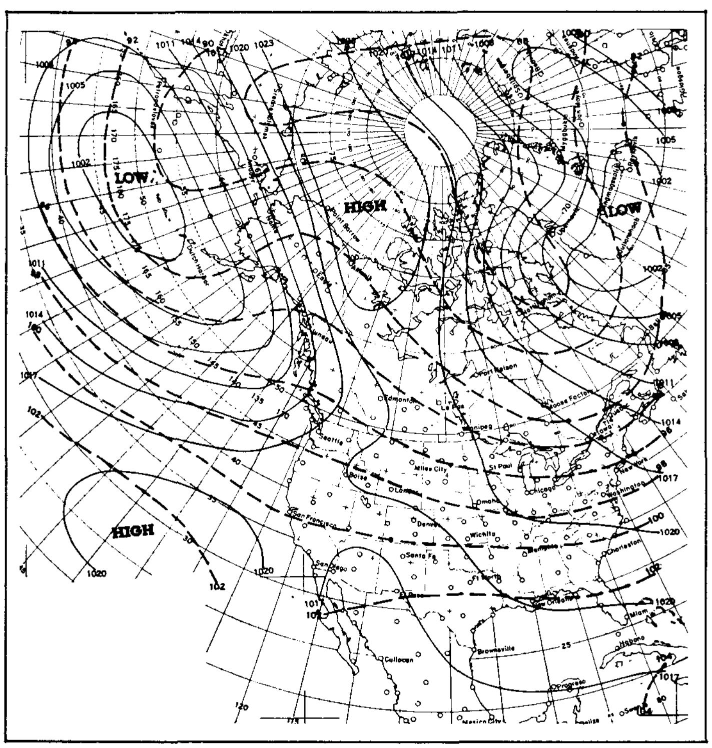

FIGURE 1.—Normal sea level isobars at 3-mb. intervals (solid lines) and 700-mb. contours at 200-foot intervals (dashed lines labeled in hundreds of feet) for the month of February.

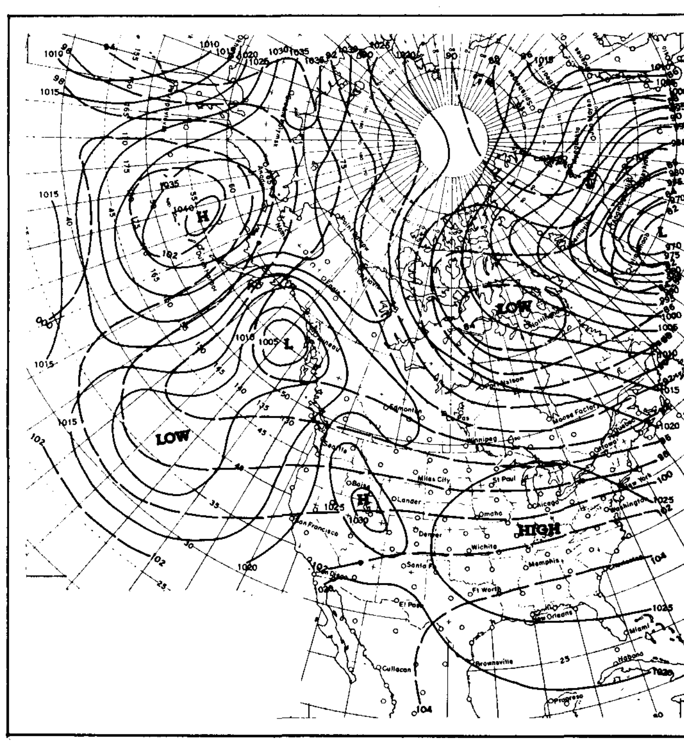

FIGURE 2.—Mean sea level isobars at 5-mb. intervals (solid lines) and 700-mb. contours at 200-foot intervals (dashed lines labeled in hundreds of feet) for the period February 1–5, 1950.

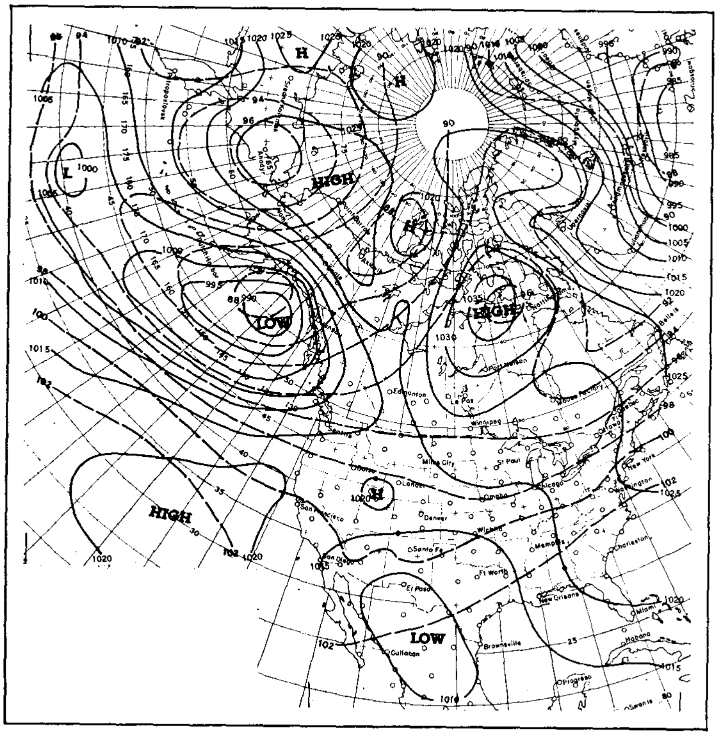

FIGURE 3.—Mean sea level isobars at 5-mb. intervals (solid lines) and 700-mb. contours at 200-foot intervals (dashed lines labeled in hundreds of feet) for the period February 8-12, 1950.

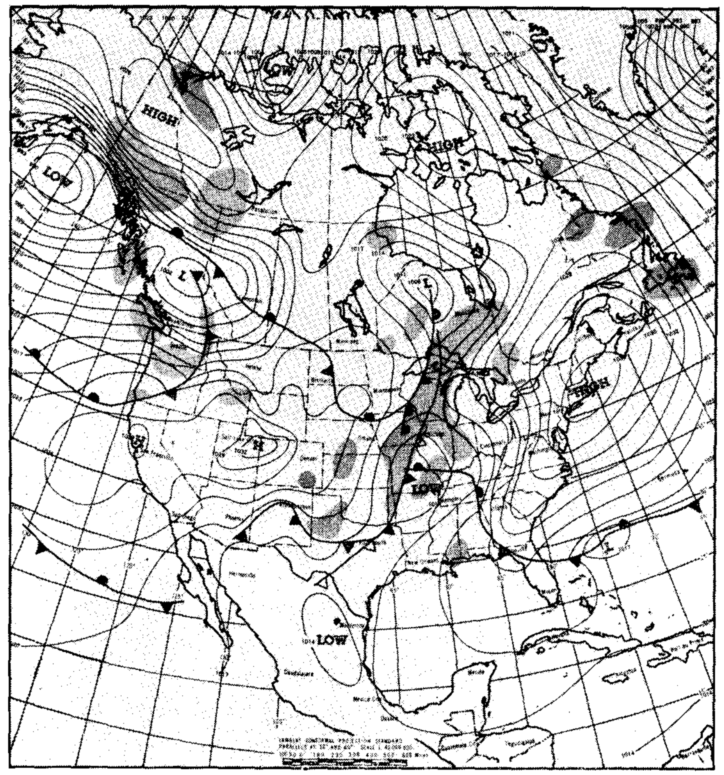

FIGURE 4.—North American surface map for 1830 GMT, February 8, 1950. Shading indicates areas of active precipitation.

particular importance in separating normally low pressure in the Aleutian region into two Low cells, one near Japan and the other in the Gulf of Alaska.

Figure 3 shows the mean sea-level pressure and mean height of the 700-mb. surface for February 8–12, 1950. There was still no appreciable flow of cold air from the Hudson Bay area into northeastern United States; instead, cold air was moving around a High which had formed in the Hudson Bay region. The High near Salt Lake City had moved southeastward since the early part of February, and a new Pacific air mass was moving into the region. Temperatures had moderated in the Pacific northwest where a new and weaker surface High was forming.

A very significant change had occurred with respect to the surface High that was previously in the Aleutian region. A break-off of the Low in the vicinity of Japan had moved northward and eastward through the Bering Sea, separating the Aleutian High from its connection to the Siberian anticyclone. The High had given way toward the southeast and was decreasing rapidly in intensity. Cold air on the east side of this High was feeding partly into the Low in the Gulf of Alaska and partly into an eastward-moving Low at about latitude 35° N. On February 8 (fig. 4) a portion of this cold air, its temperature modified by the ocean trajectory, moved into British Columbia, Washington, and Oregon, and subsequently moved eastward across the country accompanied by a Low which passed over the Great Lakes region and skirted the Hudson Bay High.

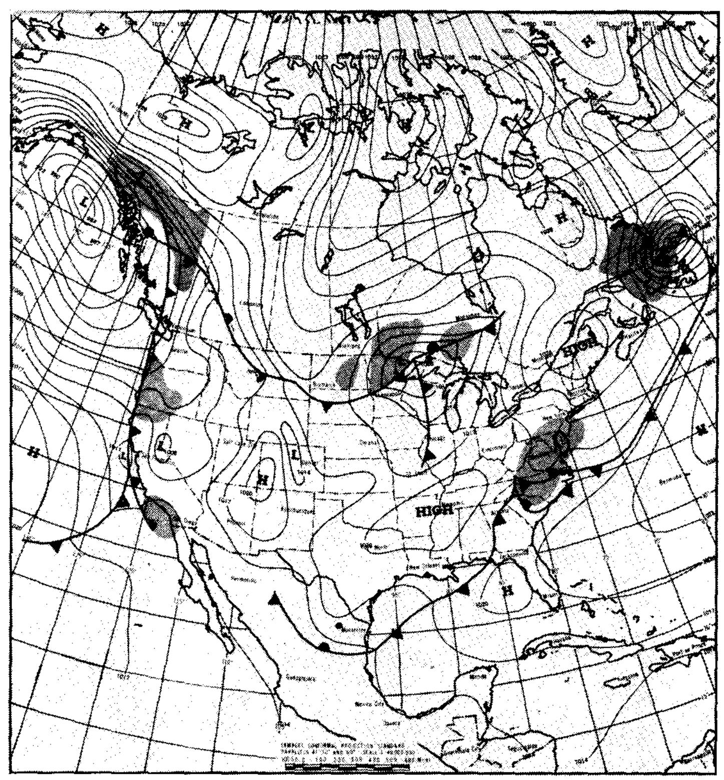

FIGURE 5.—North American surface map for 1830 GMT, February 10, 1950. Shading indicates areas of active precipitation.

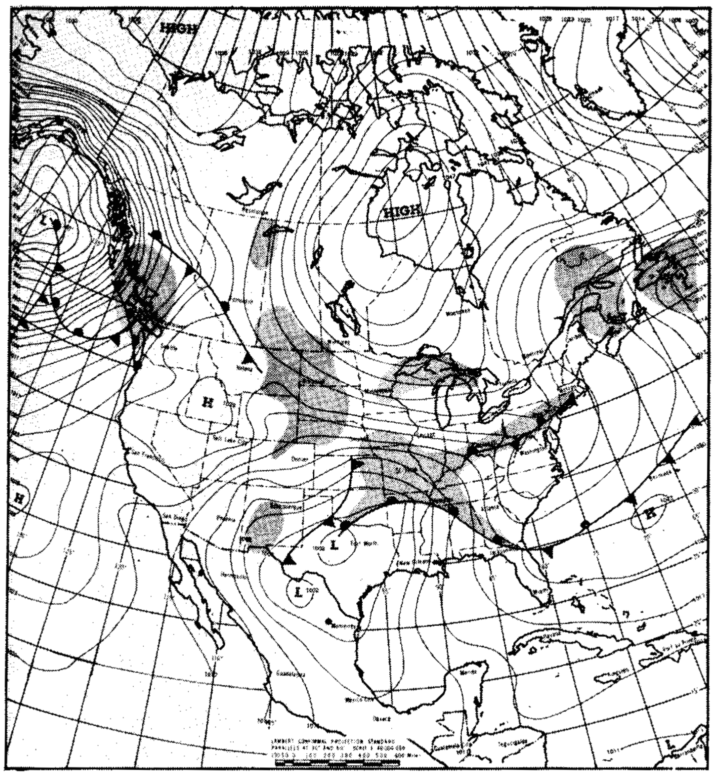

Figure 6.—North American surface map for 1830 GMT, February 12, 1950. Shading indicates areas of active precipitation.

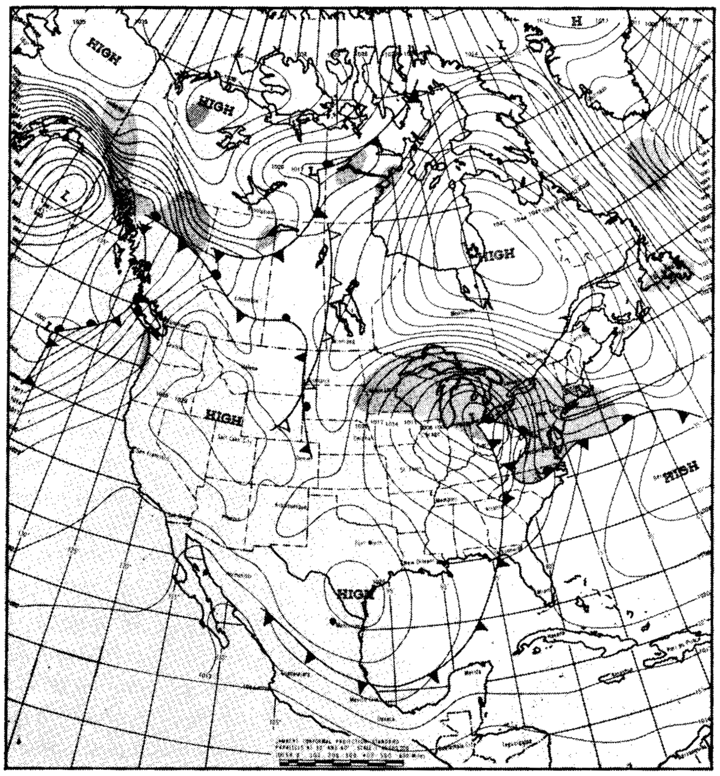

Figure 7.—North American surface map for 1830 GMT, February 14, 1950. Shading indicates areas of active precipitation.

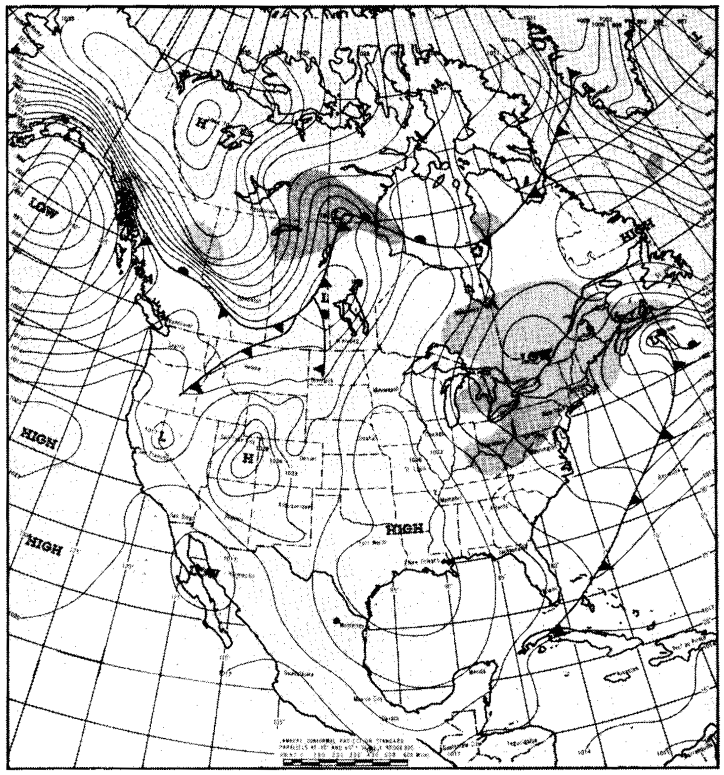

Figure 8.—North American surface map for 1830 GMT, February 16, 1950. Shading indicates areas of active precipitation.

As this Low moved eastward from the Lakes region (fig. 5) colder air from the Hudson Bay High, moving southward behind the Low, flooded the Northern Plains, Lakes region, and Northeastern States. This cold air may be seen on the surface weather map for 1830 GMT, February 12 (fig. 6) after the Low had moved into the Atlantic; it is north of the front extending from Connecticut to Indiana and over the area thence westward to the Rockies. However, temperatures were not unseasonably low.

Meanwhile, on February 10 (fig. 5), another surge of cold maritime air passed inland along the Pacific coast between Juneau and southern California. This deep mass of cold air had moved eastward and southward into the Texas and Oklahoma Panhandles and western Kansas by 1830 GMT of the 12th (fig. 6) at which time low pressure over Texas was associated with interaction between this cold maritime air and the colder air that had previously moved southward from the Hudson Bay High. Accompanying this condition, as shown on the chart for the 12th, was the only strong flow of tropical air northward from the Gulf of Mexico into the lower Mississippi Valley during the month of February. Also, surface pressure over Texas was by far the lowest during the month in that area. This low pressure intensified and moved northeastward. On the afternoon of the 14th (fig. 7) it was a well-developed cyclonic circulation centered over northern Ohio. Also, on the afternoon of the 14th, conditions were favorable for the formation of a secondary Low in the Chesapeake

Bay region. Aloft, a low-pressure trough, which was necessarily associated with the surface Low over Ohio, was moving eastward, accompanied by falling pressure along the Atlantic coast. At the same time cold maritime air was moving from the east into New Jersey and Delaware in such a way as to be deflected southward by the Appalachian Chain, while to the southward along and off the coast warm tropical maritime air was moving northward. The net result of these effects was to produce a secondary Low along the Atlantic coast which on the 15th was well developed and which produced the extensive snow cover over the Northeastern States. The secondary Low was off Nova Scotia on the 16th (fig. 8).

The extensive and rather heavy precipitation associated with both the main Low and the secondary was a result of the strong northward flow and consequent lifting of moist tropical maritime air over the deep cold air mass.

Another outbreak of cold air, which on the 16th (fig. 8) was approaching central Canada, moved across the northeastern part of the United States on the 18th and 19th, preserving the snow cover in that region and definitely ending the regime of unseasonably mild winter weather in that area.

FEATURES OF THE UPPER TROPOSPHERE

The preceding discussion outlines briefly some of the main synoptic features of the change in regime. Extreme cold in the Northwestern States moderated by the end of the first week in February but the final phase of the change in regime, marked by a change to colder and more normal weather in the eastern part of the country, took place only after an intervening series of synoptic events. These synoptic events, discussed so far mainly with respect to surface conditions, were accompanied by important changes of circulation in the upper troposphere, some aspects of which we examine in further detail in this section.

Upper air conditions are shown in figures 9–16 inclusive, the daily 500-mb. charts for 0300 GMT, February 8–15. On these charts a series of surges are followed, and their implied effect on the changing configuration of upper air pressure and flow patterns is discussed. For this purpose a surge is defined as the leading edge, marked by a wind shift or trough, of an area of strong wind. A good example of a surge is one which approached the coast of California and Oregon on February 10 (fig. 11); on the 11th (fig. 12) a secondary surge moved into central Oregon and northern California. A surge may or may not be associated with a front.

An attempt is made to follow in this series of 500-mb. charts an idea that has been utilized to some extent by the WBAN Analysis Center in forecasting changes in upper level configuration. This idea is, in substance, that a surge of more rapidly moving air parcels, on overtaking the trough line, contributes a portion of its kinetic energy toward sharpening the trough line, or conversely, as the surge deteriorates, the sharpness of the trough deteriorates. A sharpening of the trough is accompanied by some conversion of kinetic energy to potential energy (air parcels move outward across the isobars or contours toward higher pressure) and since this effect takes place in the middle and upper troposphere, it should result in lifting (and cooling) of air from below and "drawing down" of air from above in a region of resulting horizontal divergence. Some understanding of the kinematical, dynamical, and thermal results of this process aids in anticipating the changes of pressure pattern, surface and aloft, that will result from a surge or series of surges. It explains, not the large scale patterns of the upper troposphere, but rather some of the day to day changes in the meandering stream of upper westerlies.

In figures 9–16, trough lines or surges are indicated by symbols A, B, C, etc., with a subscript to indicate day of the month; for example, A_8 refers to trough A on the 8th and A_9 to the same trough on the 9th. These lines are referred to alternately as troughs or surges, depending on whether or not a surge is associated with the trough line.

In figure 9, the chart for February 8, it may be noted that along trough A_8 the reported winds south of latitude 45° N. and behind the trough, in Nevada, were weaker than the winds ahead of the trough. In Montana the winds were stronger than those reported in Minnesota. Thermal advection (warm advection indicating a rise and cold advection a fall of pressure) was an indication that the ridge along the ninetieth meridian would move rapidly eastward, and that pressures aloft along the ridge and immediately westward would fall. On the 9th (fig. 10) the trough A_9 was slightly sharper in the region of the western Great Lakes; the air then passing Sault Ste. Marie had moved through the trough and "overshot" it, being first decelerated and later deflected to the left upon entering the gradient east of the trough line. Meanwhile, the southern portion of the trough had advanced only slowly, the small trough in southwestern Utah on the 8th having been flattened into broad curves in the southern Plains area by the 9th. By the 10th (fig. 11) this trough was virtually spent. There was still a pattern for cold advection, suggesting some fall of pressure toward the east of trough A_{10}, but the gradient ahead of the trough was sufficient to deflect northeastward and accelerate slower moving air advancing through the trough line A_{10}, with consequent convergence that tended to offset any tendency toward rising pressure aloft in the middle Atlantic region.

Looking again at the chart for the 8th (fig. 9) we find trough B_8 off the Pacific coast. Its sharpness was not well defined because of scarcity of data in the area, but the wind report from the stationary ship at 50° N., 145° W. indicates that there was much stronger flow behind the trough than is suggested by the existing gradient along the British Columbia coast. On the 9th (fig. 10) there were two minor surges, B_9 and B'_9. The double structure here was evident once the system was over land, and it may have existed over the ocean, undetected, or it may have resulted from topographic effects.

For each of these troughs, B_9 and B'_9, the gradient and the wind upstream from the trough exceeded the gradient wind in the trough. Also, the air moving through the trough advanced into a region of weaker actual gradient, and as a result tended to follow a path somewhat south of the contour lines existing on the chart for the 9th.

Figure 11, for February 10, shows that troughs B_{10} and B'_{10} were still in evidence, but B'_{10} was weak. B_{10} was becoming the dominant trough as A_{10} weakened. The gradient winds over Montana and Wyoming exceeded those in the region of troughs B and B′. Also their direction led toward an area of weaker gradient in Illinois and Wisconsin. This called for a drop in pressure in the Lakes region as the air entering the region of weak gradient crossed contours toward the south, or away from the Lakes. The result may be seen on the chart for the 11th (fig. 12) where only a single trough, designated as B_{11}, is now in evidence. The same reasoning applies to the New England area for the 12th.

On the 9th (fig. 10) there was another trough in the Pacific, C_9, extending southward from the Low that had persisted in the Gulf of Alaska. Wind at 50° N., 145° W. had decreased since the previous day, and in the meantime warmer air had moved into that area accompanied by a marked rise in the height of the 500-mb. surface. The wind at 50° N., 145° W. (fig. 10) was about 15 knots stronger than the gradient wind for the contour spacing and curvature at the corresponding point along the trough. This means that such air parcels as were represented by this wind decelerated upon passing through the trough, then recurved sharply toward the northeast, carrying warm temperatures toward the British Columbia and southern Alaska coastal region, resulting in a rise of upper level pressure in that area. By the 10th (fig. 11) this had taken place.

Meanwhile the Low in the Gulf of Alaska had been deflected westward, the upper level pressures to the west and southwest of the Low falling as a deep cold air mass moved southward through western Alaska and then eastward around the Low. This movement of cold air southward, then eastward, becoming parallel to a sustained flow of warm air immediately southward and moving in the same direction, represented a buildup of solenoidal or potential energy, and also appeared as a strengthening of the gradient for westerly winds in the vicinity of latitude 45° N This strengthening of gradient deflected northward (or toward lower pressure) any air that was entering the area at this level. Then cross gradient flow accelerated it until its speed, and consequently the Coriolis force, was sufficient to recurve it toward the south. As it entered the area east of the strongest gradient, the Coriolis force deflected it farther southward toward higher pressure, especially as it passed into and through the trough C_{10}. This resulted in deceleration of the air parcels.

By the time of the chart for the 10th (fig. 11) this deceleration was taking place near the California coast, where kinetic energy was being spent partially in deepening the trough. The winds reported by an Air Force reconnaissance flight northwestward from the central California coast (fig. 11) were sufficiently strong for air parcels to move far toward the southeast in spite of the gradient. Gradient in the area into which these winds were moving was sufficiently weak, especially off the California coast, to permit a long cross-gradient trajectory before they could be decelerated sufficiently to recurve toward lower pressure. Considering the succession of parcels which were advancing toward the trough, each parcel passing through the trough would decelerate, contributing to the deepening and advance of the trough, and forming a pressure pattern into which each succeeding parcel would advance a little farther southward before it spent its kinetic energy in deepening the trough.

This resulting southward movement of mass, uncompensated by similar southward movements of mass in some area far to the north (in this case Alaska and northern Canada) required a fall of pressure aloft along the Pacific coastal areas, as was verified on February 11 (fig. 12).

On the 10th (fig. 11) there was a possible secondary trough forming at D_{10}. Its existence was not certain at this stage, but was indicated in reconnaissance wind reports near the California coast. By the 11th (fig. 12) the position for this trough and its existence seemed better established.

Meanwhile another trough, E_{11}, was becoming established in New Mexico. Winds at Albuquerque and Tucson bear out the idea that winds approaching trough C moved far to the south of the contour pattern until they were decelerated sufficiently for the weak gradient in trough C to recurve them northward. When recurved, they crossed contours toward lower pressure, being accelerated until again of sufficient speed to recurve to the right because of the Coriolis force. The leading edge of air moving in this scheme seems then to have been along E_{11}. Again, as with the system B, there may have been topographic effects which contributed to the observed effect.

Trough E persisted and advanced since the winds behind it were in excess of the gradient winds in the trough, and pressures in the trough fell because the speed of the wind in New Mexico and Arizona carried air well across the gradient in advance of the trough. Meanwhile trough C persisted because the gradient wind within the trough was slightly weaker than the wind reported on the California coast.

Meanwhile, surge D_{11} (fig. 12) was becoming a dominant feature. While C_{11} moved eastward, D_{11} was "crashing" southward, becoming sharper and deeper, and tending to merge with C_{11}. As a result, there was further deepening in the general trough somewhat ahead of trough D, as may be seen by comparing figures 12 and 13. On figure 13, the trough line C_{12} was discontinued north of the Low in Arizona and trough line D_{12} extended into the trough in

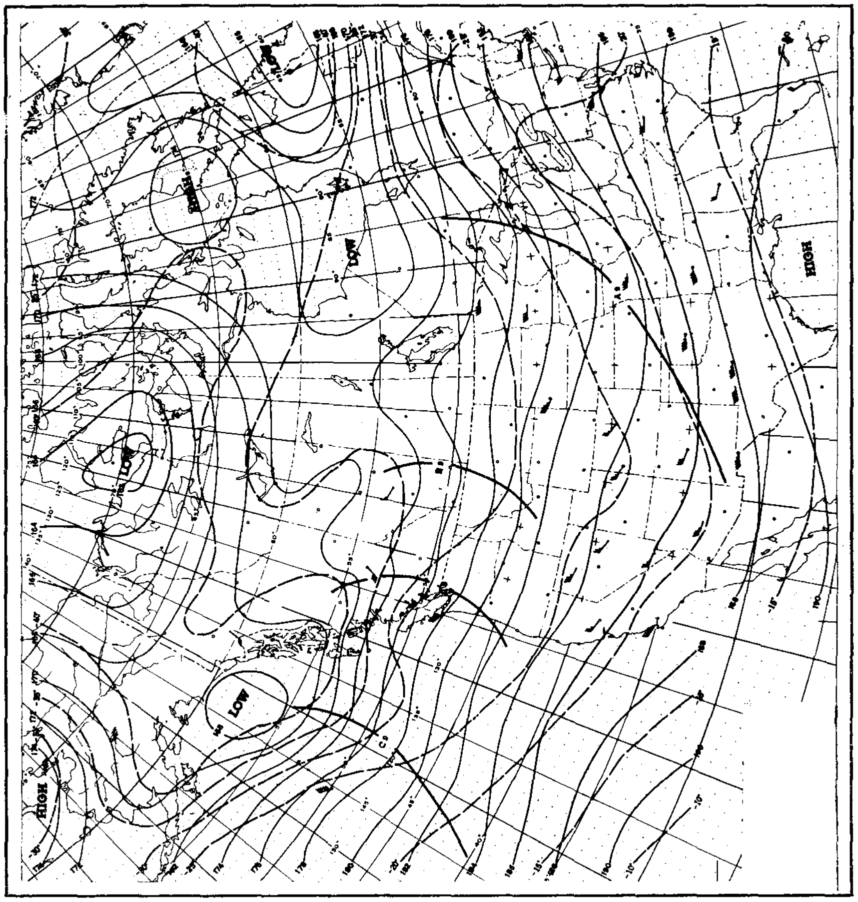

FIGURE 10.—500-mb. chart for 0300 GMT, February 9, 1950.

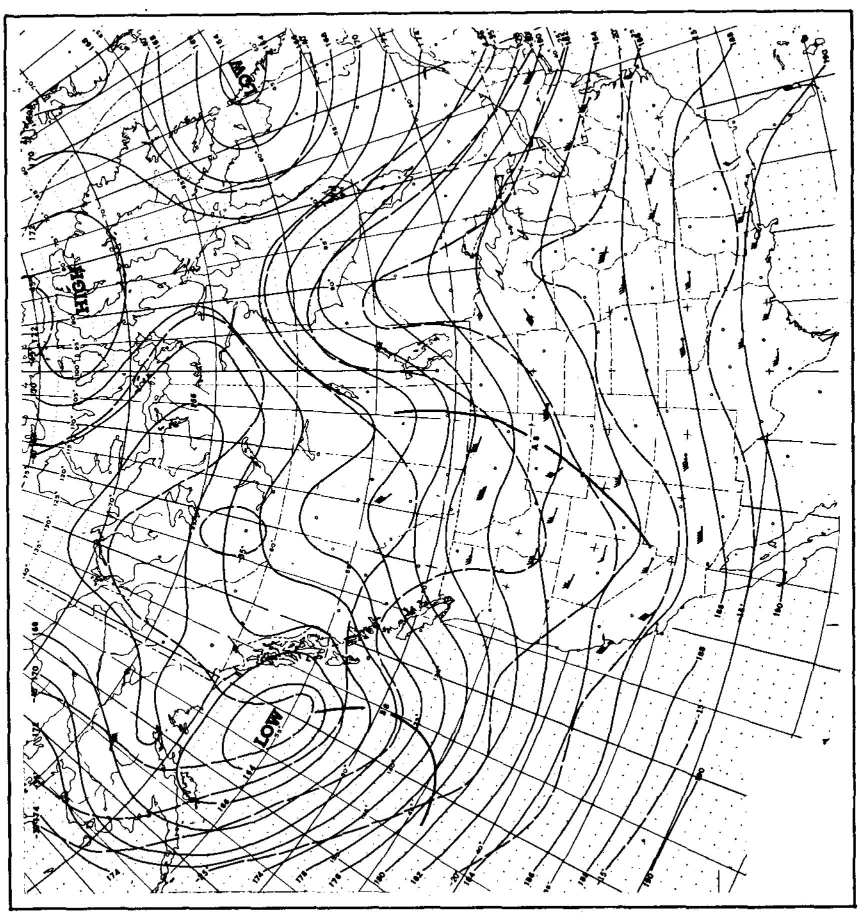

FIGURE 9.—500-mb. chart for 0300 GMT, February 8, 1950.

Contours (solid lines) at 200-foot intervals are labeled in hundreds of feet. Isotherms (dashed lines) are *drawn for intervals of 5° C.*

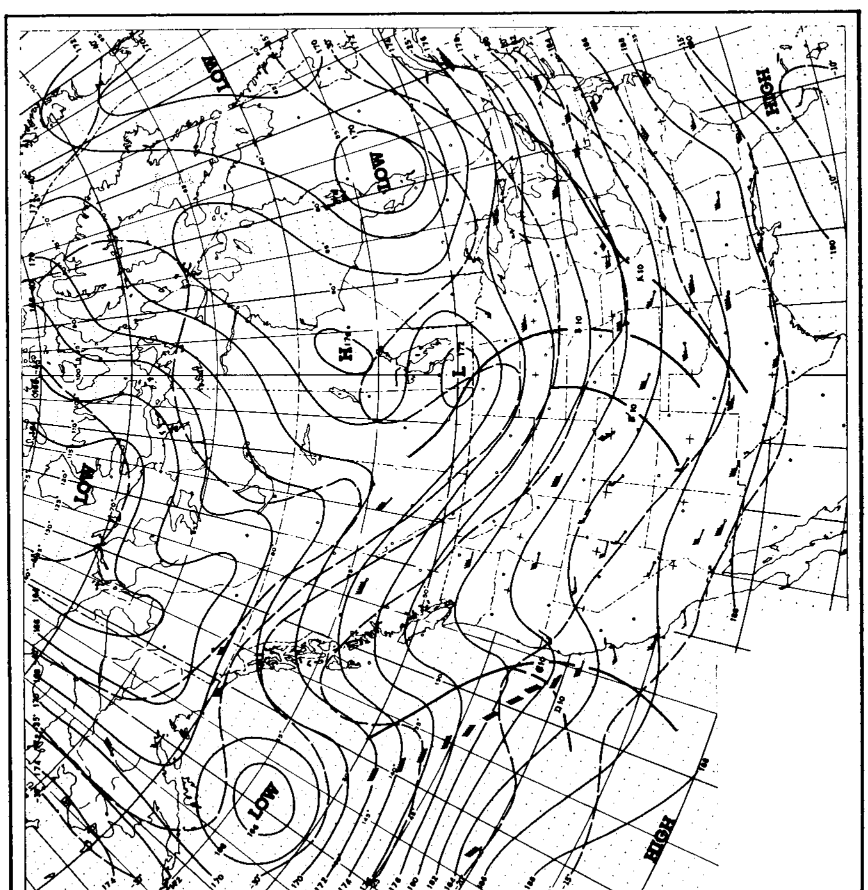

FIGURE 11.—500-mb. chart for 0300 GMT, February 10, 1950.

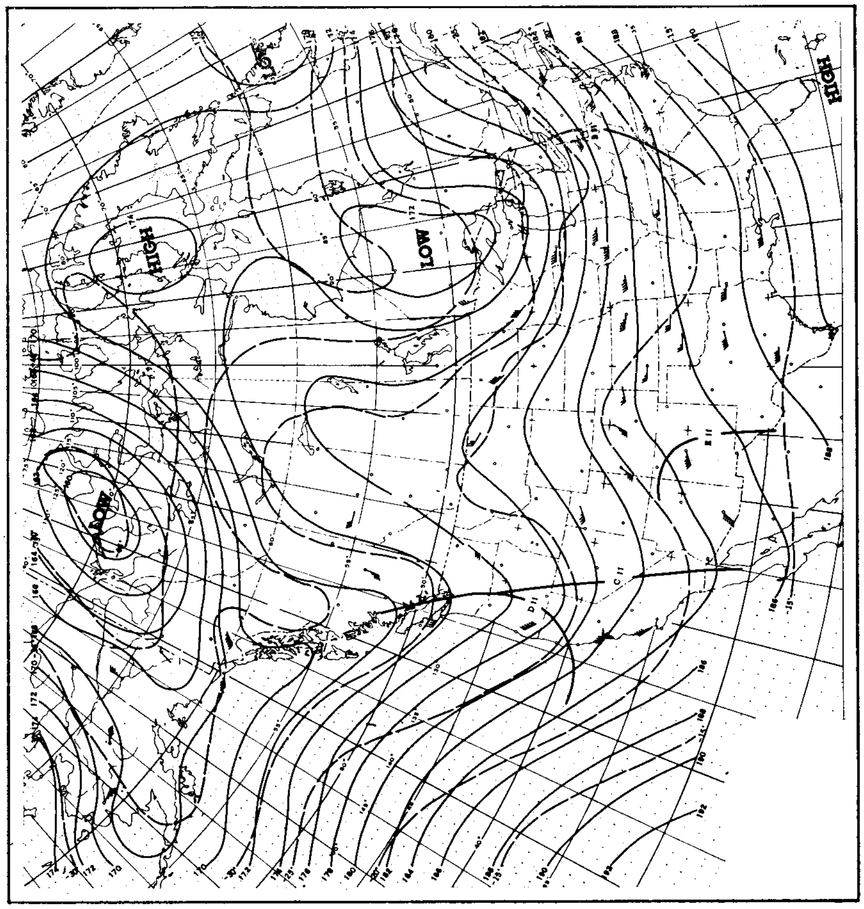

FIGURE 12.—500-mb. chart for 0300 GMT, February 11, 1950.

Contours (solid lines) at 200-foot intervals are labeled in hundreds of feet. Isotherms (dashed lines) are drawn for intervals of 5° C.

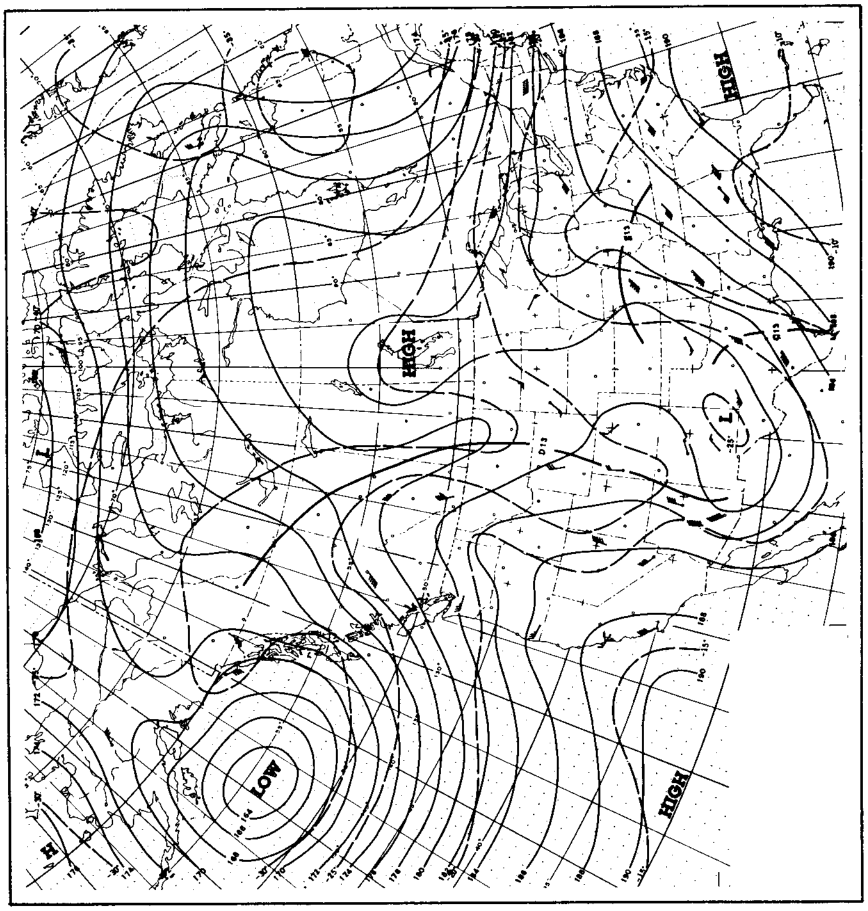

FIGURE 14.—500-mb. chart for 0300 GMT, February 13, 1950.

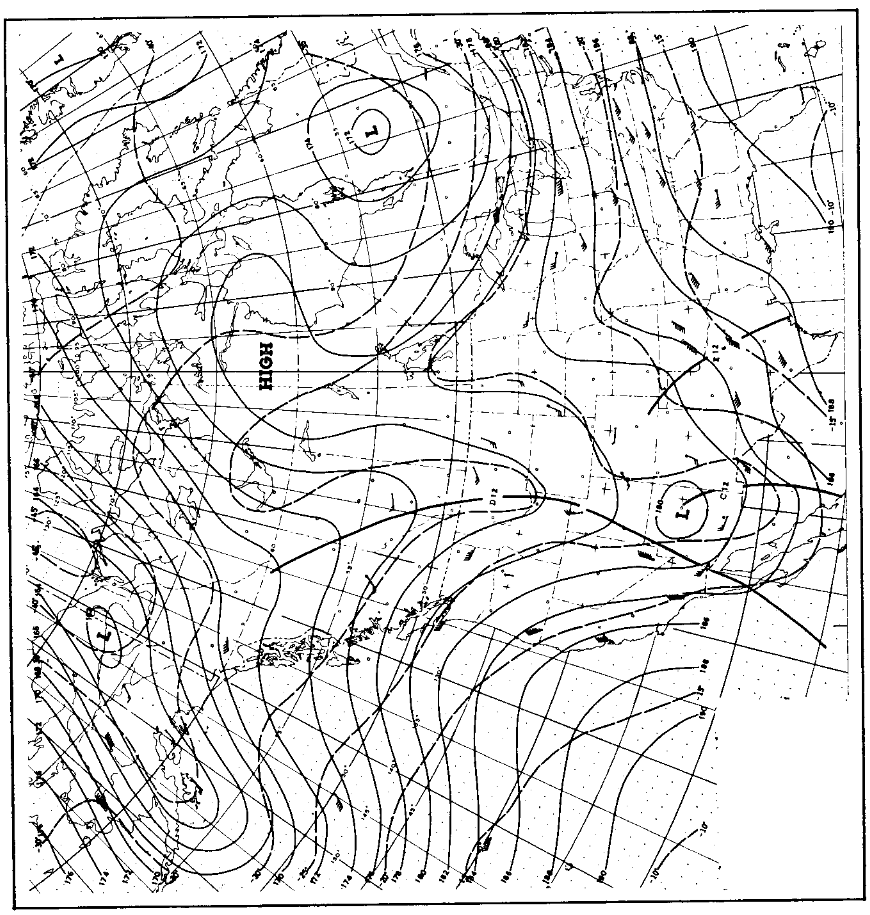

FIGURE 13.—500-mb. chart for 0300 GMT, February 12, 1950.

Contours (solid lines) at 200-foot intervals are labeled in hundreds of feet. Isotherms (dashed lines) are drawn for intervals of 5° C.

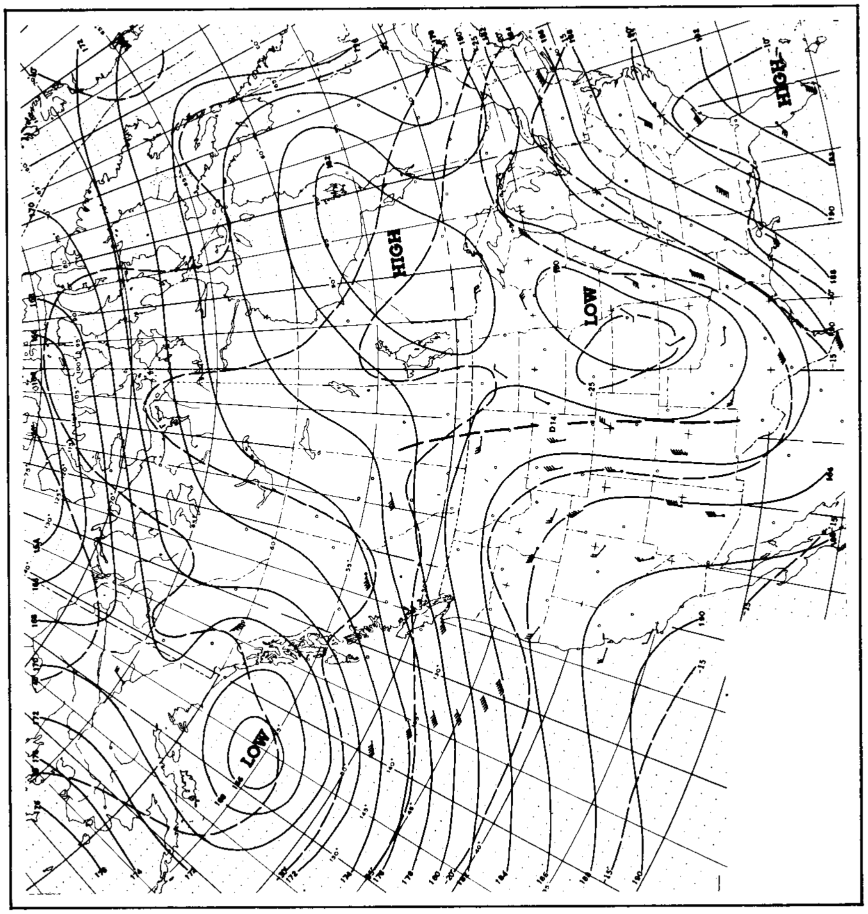

FIGURE 16.—500-mb. chart for 0300 GMT, February 15, 1950.

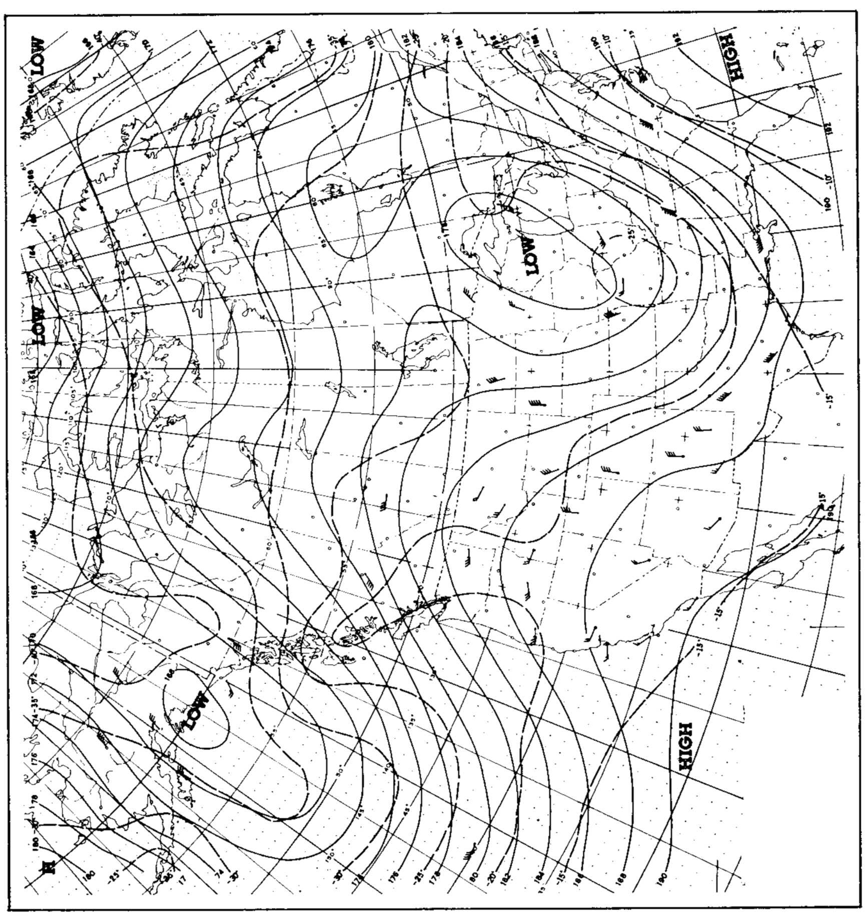

FIGURE 15.—500-mb. chart for 0300 GMT, February 14, 1950.

Contours (solid lines) at 200-foot intervals are labeled in hundreds of feet. Isotherms (dashed lines) are drawn for intervals of 5° C.

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the north in order to emphasize the homogeneous character of the flow approaching this line, in contrast to the nonhomogeneous pattern in advance of trough D_{12}. From considerations similar to those already discussed, still further deepening was to be expected in the general trough ahead of D_{12} (fig. 13) in the southwestern part of the country. Farther north, particularly in Canada, winds to the west of D_{12} were weakening, indicating no further deepening of the trough in that area. The result is verified on the chart for the 13th (fig. 14).

On the 13th (fig. 14) the gradient was temporarily stronger on the west side of the Low which was then in New Mexico. This in turn accelerated the air moving into that region, as seen at Phoenix and Tucson, but otherwise the speed of winds upstream from the main trough had by then diminished. This chart (fig. 14) is the first of the series in which the speed of the air leaving the United States in the east approached or equaled that entering the country from the west. Except for strong winds in Arizona, and those entering the area of very weak gradient ahead of trough E_{13} and ahead of trough D_{13} in eastern Wyoming and eastern Montana, the winds were mostly in fair gradient balance with the gradients they were to enter.

Divergence occurred in Iowa because of the strong wind in Missouri, and in Nebraska and South Dakota in advance of the weakening shear line D_{13}. The strong wind in Arizona strengthened the gradient in the southeast part of Texas. The light winds in Colorado and New Mexico were deflected toward the lower pressures of the Low, and contributed convergence in the southwest limb of the Low. By the 14th (fig. 15) these effects were well toward accomplishment. The only winds then markedly nongradient in speed were the light winds between the Low and the decaying shear line D_{14}. These were to be deflected toward the southern portion of the Low and to aid in its northeastward acceleration. The result is shown in figure 16, the chart for February 15. Figure 16 represents the upper air pattern approximately 9 hours after the surface conditions shown in figure 7 for February 14.

The 500-mb. pattern of February 12 shown in figure 13 immediately preceded the development of surface storm conditions over Texas as shown in figure 6. The development of the surface storm was a necessary result of the lowering of upper-level pressure over the southern Plateau area and the advance of the upper-level low-pressure area eastward. The fall in pressure at the surface took place somewhat to the eastward of the upper-level fall of pressure because of northward low-level advection of warm air in advance of the upper-level trough, requiring from elementary hydrostatic relationships that the surface Low be east of the upper-level Low. Further intensification of the surface Low was aided by the already well-developed upper-level trough, and its northeastward movement was in response to the combined effect of eastward movement of the upper-level trough and the northward advection of warm air at low levels ahead of the upper-level trough.

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